Συνέδρια της Ελληνικής Επιστημονικής Ένωσης Τεχνολογιών Πληροφορίας & Επικοινωνιών στην Εκπαίδευση

Τόμ. 1 (2002)

3ο Συνέδριο ΕΤΠΕ «Οι ΤΠΕ στην Εκπαίδευση»

Policies for Educational Innovation with New Technologies

H. Ulrich Hoppe, Chronis Kynigos, Rossella Magli

Βιβλιογραφική αναφορά:

Hoppe, H. U., Kynigos, C., & Magli, R. (2026). Policies for Educational Innovation with New Technologies . *Συνέδρια της Ελληνικής Επιστημονικής Ένωσης Τεχνολογιών Πληροφορίας & Επικοινωνιών στην Εκπαίδευση*, *1*, 203–213. ανακτήθηκε από https://eproceedings.epublishing.ekt.gr/index.php/cetpe/article/view/8788

Policies for Educational Innovation with New Technologies

H. Ulrich Hoppe, Chronis Kynigos, Rossella Magli
University of Duisburg, Germany, University of Athens, Greece, Scienter S.I., Italy
hoppe@informatik.uni-duisburg.de, kynigos@cti.gr, rossella-magli@tiscalinet.be

SUMMARY

In the framework of the "Schools of Tomorrow" initiative, the European project 'SEED'[1] aims at fostering educational innovation with New Technologies as a cultural change in three distinct communities in Germany, Greece and Switzerland. Each community consists of institutionally distributed members who engage in the mutual construction of tools, resources and scenarios for innovative educational practice. These tools, resources and scenarios are mutually negotiated within each community and their construction is in each case grounded in real classroom experience. The project focuses not only on the products of these communities, but also on the methods by which they are supported and the nature of their growth. By uprooting their members from the constraints posed by the system and their organisations and bringing them to jointly reflect and craft educational innovation, the project aims to study how making use of these "best practice examples" can become one of the methods the educational policy maker may have to 'jolt' mindsets in educational practice. Given that the time scale of the process of mindset change is a different order of magnitude to that which traditionally interests the policy maker, the project aims to study the generation of this type of communities as a process of both tangible value for educational policy and potential for large scale systemic reform. At the current stage of the project, we are more concerned with a deeper understanding of the questions and the space of potential answers than with narrowing down the answers to fixed suggestions or recipes.

KEYWORDS: *appropriation of technology, computational media, changing mindsets*

WHAT CONSTITUTES INNOVATION AND HOW IS IT MANIFESTED?

With the advent of the post-modern "information society", it is assumed that new types of social and intellectual skills and knowledge are needed, favouring, e.g., team skills over individual performance and meta-cognitive skills over traditional cognitive competencies such as being able to perform complex mathematical calculations. Educational institutions and practitioners are already feeling the pressure to adapt to this new society. Educational policy makers, however, have been perceiving the pending need for reform as an engineering task, i.e. that there is a demand defined by the supposedly well-known requirements of the information society, so now we have to re-engineer the educational system to meet these requirements.

From an educational point of view, however, New Technologies can at best provide the educational community with sources of information and media for communication and expression. Only if this technology is put to *educational* use, it may support richer learning activity based on

symbolic expression, construction, experimentation, investigation, data handling. In such a case, it may also support the generation of social learning modes where authentic questioning, research, use of human and artificial feedback, argumentation become recognized and valued in school. It may enable focus on learning process, as opposed to learning content, emphasis on collective knowledge and "strength" as opposed to the encouragement of individual performances, development of children's autonomy, self-expression and creativity in the context of belonging to different communities (the class, the school, the teachers, the parents, the local community, the city e.t.c.). It may be used as a catalyst for re-evaluation of the status of play as a learning process and consequent blurring of the traditional distinction between work and play, re-evaluation of the status of pleasure in schools, reconsideration of the locus of authority. So, can the engineering approach to educational reform enable such use of New Technologies?

We begin by suggesting that there is more to digital technologies than the techno-centric engineering perspective that they may bring about change acting as "innovation portal". We argue that new digital media have an inherent educational value as interactive and expressive tools of thought, allowing for learning activity such as the one just mentioned. However, a very big difficulty seems to lie in the acceptance by the school environment (and more broadly by the specific economic system of the western post-industrial world) of children's intellectual expressiveness and creativity envisioned by the above use of technology. Successful students' performance (especially at the secondary level) is often considered as that expressing conformity to teachers' expectations, who sometimes just mediate curriculum expectations, which in turn tend to be seen more and more in the terms suggested by the economic imperatives. Teachers individually trying out innovations and developing personal pedagogies bump into insurmountable organisational difficulties, rigidity of curricula, even self-desecurisation for having to adventure beyond their discipline field. The systemic context thus does not afford representational flexibility, creativity, autonomy, constructionism, social mode of learning. We cannot thus expect such practice to develop merely by the infusion and use of this new medium. Even though this particular medium may enable the expressive and learning activity we described in ways not possible with static media, the critical point is contextual or 'mindset' change, including the institutional one. Thus our primary concern is not the optimisation of knowledge transmission processes but the use of digital media to enhance intellectual expressiveness and creativity, metaphorically speaking as "wings for the mind". Thus, rather than re-engineering education, we come to re-defining the traditional notion of education in its broad sense, at least in its aspect of intellectual development.

We thus do not believe in a "social engineering" approach. First, there are too many unknowns in the premises: The nature of the society and economy of the future are not at all clear and even less clear are the implications for the professional and private life of individuals. Also, the engineering approach does not take into account current definitions of European public education which are not in first place a preparation for the societal requirements (Kontogiannopoulou – Polidorides, 1996), but explicitly defined as an institution to foster the personal and intellectual development of the "educandi". W. v. Humboldt (1767-1835), one of the conceptual architects of today's educational institutions in Germany defines "Bildung" (i.e., education in the sense of moral and intellectual development) as the "involvement of the self with the surrounding world in the most general, most lively and free interaction". This understanding of "Bildung" has been rephrased as "Weltaneignung", i.e., as "appropriation of the world" (cf. Tenorth, 1994, p. 45/6). We believe that the concept of appropriation is still very valuable to positively define desired educational processes, and we will revisit it later.

Moreover, from a systemic educational policy perspective, the engineering approach is an illusion, even though it is the one most traditionally adopted (Prawat, 1996). We suggest that the use of New Technologies, for instance, will not trigger educational innovation by themselves merely by equipping the educational system with the necessary technical infrastructure, hardware and software and by subsequently implementing a 'Total Quality Management' style systemic reform (Prawat, 1996, Papert, 1993). Educational systems are conservative, rigid institutions by nature and thus inflexible to the rate and quality of change feasible within the Information Society. In this sense, it would not be reasonable to expect rapid developments constituting innovations within respective educational paradigms such as the one in Germany for instance. Papert (1993) and Hoyles (1993), for instance, have argued that the school and the educational system seem to fight back against innovation by transforming it so that it finally fits in traditional practice, thus neutralizing its impact. From the point of view of reform initiatives, the methods usually employed are perceived as an engineering task within the 'Total Quality Management' paradigm where detailed and precise expectations are mediated to educational staff. The reform is then assessed by means of the extent to which these expectations are met by measuring performances.

In education, this paradigm for reform does not work. The educational system is a grown functional part of the society. As such, it forms a sub-system which is in many aspects self-referential and self-sufficient (Luhmann & Schorr, 1982). Although Luhmann & Schorr argue for more "technological" approaches in education, they underline that the inherent systemic constraints have to be understood and considered in any attempt to foster systematic change. Essentially, we cannot re-engineer or adapt the system from the outside, the system has to adapt itself from within. Prawat, (1996) and Grossman et. al. (2000), for instance, have argued for a 'Learning Community' approach to educational reform, where expectations are articulated in broader terms, leaving initiative for teachers to take the role of participators and shapers of the reform by means of being actively engaged in reflective pedagogy through interaction in teacher communities of practice. Evaluating the reform requires new methods of looking at social processes rather than results and needs to allow for arduous, messy procedures eventually leading to change, rather than linear ones. This implies that the reformist cannot pre-define the outcome in a positivistic way. They may, however, design change in broader terms and then support local perturbations through recognition, opportunity creation, availability of technological and social infrastructures and feedback structures and then allow for a new equilibrium. In many cases, local interventions (such as researcher - led ones) are themselves pedagogically inspired and not random perturbations. In each case, however, it is the meanings and the actions which the practitioners generate as a result of the intervention that matters and that can often be quite different – but not less valuable - to the articulated aims of the intervention.

APPROPRIATION OF INTERACTIVE DIGITAL MEDIA AS EXPRESSIVE TOOLS

THE NOTION OF APPROPRIATION

In the Marxist tradition, the concept of appropriation is primarily interpreted as appropriation of tools with a specific focus on the means of (industrial) production. This tool interpretation has been taken up in social constructivism and "Activity Theory" (e.g., Cole & Engeström, 1993). In the educational context, the notion of appropriation has been used to characterise the basic mechanisms of learning or "internalisation" in a Vygotskian perspective (cf. Brown et al., 1993, pp. 191-94). Here, the term "appropriation" denotes the mutual or social process of knowledge construction. But what is actually appropriated in this process, i.e. what is the object of

appropriation? This remains much less clear in dialogical or interactional interpretations than in the tool view. Schwartz (1999) points out that the view of *appropriation as internalisation*, a process in which the individual receives something from the surrounding social environment or culture, misses the important aspect of *production* (pp. 207-09). Production, in this sense, cannot be identified with the internalised processes of knowledge construction, it is a creative transformational process by acting in the world. Schwartz sees production as an add-on to appropriation and not already contained in it. Humboldt's notion of "Weltaneignung" means an *active* appropriation of the world which comprises both aspects of internalisation and production.

Within the field of mathematical learning with New Technologies, Papert's idea of learning–by–doing in the 80's (Papert, 1980) was re-articulated as the notion of *constructionism* in the 90's (Kafai et. al., 1996). Inherent in both is the study of learning processes within contexts where students literally construct computational (or other) artefacts and where learning takes place from processes like appropriation and internalisation which are inherent in constructions with computational media. If we dare use the terminology in the above paragraph for such a different context, constructionism would imply the process of internalisation during production. In any case, this idea of learning by means of creating computational artefacts implies that what is important in using such a medium is not only the functionality of the medium itself, but the meanings generated and expressed by the user as a result of interacting with the medium and the context of the activity. This, in fact, involves a serious change of focus with respect to learning with the use of such media. It means that even if the same tool is given to different people, each one will appropriate its use in a different way and thus there is no point in designing innovation by looking at the functionality of the media alone. A recent international meta-study analysed 662 (!) examples of research on computers in mathematics learning, and found that the studies focused on one or more of the following dimensions of the use of technology: epistemological, instrumental, institutional, cognitive, teacher role, didactical situation and human machine interaction (Lagrange et al., 2001). In this section we discuss the importance of the *instrumental* perspective, which makes a clear distinction between a tool and an instrument: a tool is a technological artefact, while an instrument refers to how that artefact is mentally constructed by the user, that is, how the user conceives of its constraints and possibilities.

As a fundamentum for our view of educational processes, we will thus elaborate an understanding of appropriation which includes *productive activity and expression* and which takes the instrumentalist view of *media as the object of appropriation*. We do not postulate that what is appropriated should be reduced to "media" in a general understanding of the term appropriation. We want to pursue a specific perspective as our conceptual guideline for educational innovation. A related approach, namely focussing on the notion of appropriation on language as a medium, has been suggested by Baker et al (1999): "Collaborative learning will be associated with a gradual transition from the use of language as a medium for grounding communication (pragmatic) to grounding on the level of the medium itself (semantic), leading to appropriation of the medium" (p. 46). Although we do not exclude language as a medium, we advocate a broader view of "expressive media" as introduced by J. Dewey in his book "Art as Experience" (1934) and a little later by A. diSessa in "Changing Minds" (2000). Inherent in both is the notion coined by Papert (1980) of 'bricolage', i.e. learning by constructing artefacts for the sake of production or creative transformational process by acting in the world.

Before elaborating the notion of (expressive) media as the target we want to clarify our understanding of the process characteristics of appropriation in education. How does appropriation take place? We see the following basic ingredients:

- gradual improvement of mastery in using certain media to express and communicate ideas;
- development of intellectual and artistic creativity which is reified in the form of products externalised and substantiated in a medium;
- active involvement in a learning community, in our field of application particularly the classroom community;
- the adoption of different roles in collaborative learning scenarios, including, e.g., the roles of "initiator-proposer", "listener" or "critic".

DEWEY'S CONCEPT OF EXPRESSIVE MEDIA

Dewey's notion of media (Dewey, 1934) focuses on their function as means of intellectual and artistic expression, far from the function of representing content! This concept of expressive media subsumes notations as used in mathematics, music and language as well as modern "digital media".

A media-theoretical re-interpretation and adaptation of Dewey's concept of media has recently been presented by Vogel (2001) as a starting point for developing a definition of rationality which is not grounded on a prior notion language as, e.g., in linguistic pragmatics. The alternative opened by Dewey and adopted by Vogel takes action, particularly expressive and communicative action as a starting point. Vogel's interpretation of Dewey is condensed into five criteria:

1. M is a medium if (by definition)
2. M is used intentionally;
3. M is used for expressive (and/or communicative) purposes;
4. M is a genuine constituent of the acts or products generated;
5. The specific use of M is
    - established in the framework of a performative practice (culture), or
    - constituted by social rules;
    - M allows for producing expressive acts or artefacts which can be publicly performed or exhibited and which constitute an integrated experiential episode for certain observers.

Evidently, (5) can be especially related to the use of media in arts. Leaving this apart, (1) - (4) give an adequate and useful characterisation of media also in a broader, more general sense. Compliant with this definition it is evident that, e.g., voice, writing systems, formal notations, but also the stone which is carved by a sculptor are all media. The third criterion expresses the claim that the medium in which something is construed or expressed is closely related to its content, not in the extreme sense of McLuhan's statement "the medium is the message" (McLuhan, 1964). Rather, the medium leaves its "trace" on the content being expressed (Krämer, 1998) such as a speakers voice, beyond the illocutionary aspects of intonation, lends a specific flavour to what is said.

Each medium has a representational potential and specific representational characteristics. The above criteria do not make very explicit assumptions about such representational qualities. To demonstrate that there is still a wide range of interpretations, Vogel (p. 157) uses the example of a man who is threatening another person by lifting and waving his umbrella. Is the umbrella in this

example a medium? At least, criteria (1)-(4) apply quite directly. Yet, the representational potential of an umbrella is very limited. We could say that the qualification of something as being a medium or not depends on the context and actual use. This degree of freedom may be needed and well justified when interpreting modern arts. For our purposes and, again, giving up the claim of defining media in general, we want to postulate certain representational qualities in order to qualify something as a medium. An important aspect is the one of flexibly structuring what is being expressed or represented. E.g., the representational flexibility of notation systems (ranging from alphabets to programming languages) stems from what could be called ”symbolic compositionality”: obeying certain syntactic constraints of the medium itself, a wide, often infinite, variety of expressions with different meanings can be generated. This is not only true for formalised representation systems, a similar kind of compositional or combinatorial flexibility can be found in painting and musical performance (as distinguished from musical composition which already uses a formalised notation).

Based on this consideration of representational qualities, we suggest to complement the 5th criterion by including the following:

> M affords representational flexibility through a compositional or combinatorial structuring of expressions.

We claim that interactive digital media constitute *new forms* of intellectual and artistic expression in the very sense of Dewey’s principles (including our modification). If this claim is accepted and considering that education or “Bildung” strives for helping the “educandi” in their appropriation of the world with a special emphasis on intellectual development, it is a *must* for the educational system to incorporate new digital media as tools for intellectual expression and production. A serious corollary is that this view has to be clearly distinguished from the “computer literacy” argument: Usually, the quest for computer literacy is justified by the argument that the mastery of computers and other digital technologies is a basic cultural skill, both as a practical demand in everyday life and a prerequisite of many professional skills in the information society. This argument has been frequently reiterated and also challenged in current discussions (for a critique from an educational point of view, c.f., e.g., Tenorth, 1994, p. 76 ff.). In our approach, computer literacy is not more than a side effect, our central claims are derived from educational principles not from external skill requirements.

The practical developments within the SEED project (see, e.g. Kynigos, 2002) reflect our view of expressive and communicative use of media in different ways. The following lines of development are explicitly pursued:

- ⇨ The provision of flexible authoring tool-kits which allow teachers to create their own interactive learning materials or microworlds (see diSessa, 1997, Kynigos, 2001 for an elaboration of this idea). These tool kits are made up of educational software components as building blocks. The pedagogical vision behind this approach is the one of *teachers as creators of interactive materials which stimulate constructive and intellectually challenging activities on the part of the students.*

- ⇨ The provision of collaborative mind tools as a *synthesis of constructionist and collaborative learning environments* (see, for example, Kynigos et al, in press, Hoppe et al., 2000,

Pinkwart et al., 2002) Here, computer support for collaborative learning is not limited to computer-mediated communication, but allows for creating and processing computational objects.

- ⇨ The provision of *cooperation tools for communities of educators and learners*, including portal technologies and content management systems (see, for example, Dillenbourg, Schneider ?).

In conclusion, the overbearing mindset of computational literacy as a vehicle for educational change misses the point in that it portrays a naïve ontological notion of technology as an object to learn in order to enhance skills allowing us to do more effectively what we have been doing so far in education. This does not constitute educational change and the innovation we have portrayed, which we argue to be essential and which is made even more possible with the advent of this very technology, will not come. In this section, we make our first effort to argue for two crucial issues in order to understand the problem and the potential carried with new technologies, the instrumentalist view of appropriation and the notion of technology as expressive media.

TEACHERS' MINDSETS

One of the crucial agents for educational change is the teacher community. In the field of education and educational psychology, this has only recently been recognised since for a small number of decades, the teacher was perceived as the technical mediator of a predefined curriculum and learning as an individual process of physiological cognitive growth. In the past 20 years or so, there has been rapid development in the understanding of teachers and the role they play in learning. It began by research into teachers' beliefs about teaching and learning process and conceptions of their discipline. It went on to perceive of the teacher as a reflective practitioner actively generating their personal pedagogy within the context of their classroom (Hoyles, 1992). At the systemic level, however, the role apparently prescribed for teachers remains that of content delivery. In practice, there are of course many teachers who actively reflect and reformulate their practice, who try out innovations which are by definition sensitive to the context of the classroom and their students. However, they are not encouraged to do so by the systemic and organisational context and often feel that this is an uphill struggle which no one recognises of values besides the students themselves. The system prescribes a busy ant – like existence for the teacher's day - to - day job, not leaving much space for concentrated planning or reflection.

It is common sense, that in such conditions, the way new technologies are portrayed by the system to the teacher community and the way in which inevitably this community tends to perceive the technology is as a new means to optimise the 'pipeline' metaphor for education. The new technologies provide the means for effective and pluralistic availability and delivery of content. The terms "multimedia" and "networking" have thus taken prominent positions in the rhetoric for educational reform, even though they only refer to content (other than text) and its transmission. This view neglects the expressive, communicative and productive potential of interactive digital media which, in our perspective, is the essence for defining innovative educational practice around new media. The content centred view of digital media neutralises the role of the teacher even more, in that it does not do anything for the development of the teaching profession from static to developmental, since any related teacher education is conceived as a computer literacy course for the teacher to passively receive more content quicker. This allows for inexpensive short, one off, intensive seminars to enable the teachers to receive and deliver more curriculum, leaving them completely out of upgrading the quality of their work and empowering them with expressive

media which they may appropriate themselves and design contexts for empowering their students in the same ways.

So, in discussing the notion of changing teachers' mindsets, we do not join the rhetoric which victimises the teacher by assessing the extent to which they deliver the curriculum accurately. On the contrary, we study the ways in which the teachers in the three communities of the project were supported in order to articulate a framework for a policy empowering the teacher, by providing rich opportunity for continual professional development, supporting the design and implementation of innovation grounded in and across classrooms and consisting of the ideas discussed in the first section of this paper.

STRATEGIES AND GUIDING QUESTIONS FOR EVALUATION

To observe, document and analyse the processes described, we have chosen to follow an ethnographic approach, that is, a "slow" method that patiently collects qualitative data through participant observation over extended periods of time and only at a second stage systematises them into conceptual categories, as the researchers progressively approach the system of meanings and values of the groups they observe. The limited duration of our project does not allow for a complete ethnographic analysis of the whole process with equal emphasis: teachers' change of mindset, transfer of this change in their relation to children and in relation to their understanding of the school place and role, and finally, percolation of this change outside the specific experience. We made the choice to focus on the change of the mindsets of the teachers in our three communities and understand the interactions within these communities, which played an important role in this process. This is not to say that we will ignore what these teacher do in their classrooms with the innovations they create, nor that we will leave out other participants of these communities such as educational researchers and technical people. Our aim, however, is to focus on the potential of generating these institutionally distributed communities for the system to then make use of their products and methods as "exemplary cases of practice".

Being our research still ongoing, we can only portray the issues that seem to be emerging from our preliminary analysis of the three sites as important to be further explored ethnographically and through in-depth interviews and biographies. Their list is not exhaustive and will be enriched and reformulated as our project work progresses.

Collaboration

- Institutional conditions for generating a community of interests, role of the technology in the process (constructive vs. disruptive, in what sense?), role and description of other factors;
- Appraisal of the way teachers collaborate: contexts and activities, "social" sharing of experiences, "utilitarian" sharing of experiences, "loyalties": with whom (disciplinary, inter-disciplinary, personal affinities of different sorts), impact on hierarchy interaction;
- Appraisal of the way teachers have experienced the history of this collaboration (motivation, resistance, achievements etc.);
- Transfer of collaborative methods within the classroom.

Role

- How do teachers perceive their role?
- What changes have there been in their own perception and the researchers' appraisal in relation to frustrations, active/pro-active attitudes, motivation, professional status, social status…?

- How do they (will they) translate this change of role in relation to pupils, colleagues, school hierarchies, local communities? How do teachers envisage the roles that these (pupils, colleagues, school hierarchies, local communities) will or should have? In what sense is there a change from present situation?

Status of knowledge

- Are there changes in the way teachers perceive the status of knowledge?
- What changes have there been in this perception (teachers' perception and the researchers' appraisal)? In relation to the locus of authority that gives legitimacy to knowledge, in relation to discipline divisions, in relation to learning processes…
- How does their appraisal of the status of knowledge determine changes in relation to pupils, colleagues, school hierarchies, local communities and "external world"? And in relation to "informal" education?

Perception of technology

- The dominating perception of digital media: productivity tools, communication tools, knowledge containers, ... ?
- Perceived social impact of digital media and tools: federation of people, isolation, conflict…? Tailored to specific needs or flexible to accommodate different needs?
- What specific purposes can it best serve for teachers and children?

Relationship of school with "outside world"

- Has this relation changed in teachers' views thanks to the SEED experience? Should it change? In what sense? What actors should be "working with" schools? In what capacities, with which roles, bringing what competencies, what values? How does this change school dynamics?
- What will the teachers' role be in relation to the external actors (proactive, reactive, collaborative…)?

Curriculum

- How do teachers perceive curriculum?
- Would they define it as : A "holy text"? A text to be followed with criticism? A text to be subverted whenever possible? A necessary evil? A precious guideline? A heavy burden?…
- What strategies can be put in place to accomodate changes and innovation in the curriculum?
- Do teachers envisage greater difficulties after the SEED experience to follow the curriculum or do they feel they can, on the contrary, enhance it?

CONCLUDING THOUGHTS

This paper discusses some issues emerging as pertinent for policy for educational change with New Technologies, from the experience within the SEED project at the end of its first year. We argue that the engineering or Total Quality Management perspective to educational reform by which technology is rapidly inserted for the optimisation of content delivery will not have any bearing on any qualitative change in teaching and learning in school, nor will it liberate and legitimise teachers and students attempting to engage in such a change. Three issues which play a central role and are yet completely underestimated by the system are that the real potential for New Technologies can be understood if they are perceived as new expressive media, that this media will be appropriated by society in a multitude of ways and education can channel this appropriation to be conducive to qualitative change and that a huge investment needs to be made to empower teachers to play a more formative role in this process. The experience in generating

and supporting the three institutionally distributed communities in the project is already proving an inspiration for articulating new strategies and paradigms for systemic change.

NOTES

[1]Project 'SEED': Seeding cultural change in the School System through the Generation of Communities Engaged in Integrated Educational and Technological Innovation, European Community, 5th Support framework, Information Society Technologies, IST – 2000 – 25214, 2001-2004.

REFERENCES

Baker, M.; Hansen, T.; Joiner, R.; Traum, D. (1999). The role of grounding in collaborative learning tasks. In Dillenbourg, P. (Ed.) (1999), *Collaborative learning: Cognitive and computational approaches* (pp. 31-63). Amsterdam et al.: Elsevier Science.

Brown, A.L.; Aswh, D.; Rutherford, M.; Nakagawa, K.; Gordon, A.; Campione, J.C. (1993). Distributed expertise in the classroom. In G. Salomon (Ed.), *Distributed Cognitions* (pp. 188-228). Cambridge, MA: Cambridge University Press.

Cole, M. & Engeström, Y. (1993). A cultural-historical approach to distributed cognition. In G. Salomon (Ed.), *Distributed Cognitions* (pp. 1-46). Cambridge, MA: Cambridge University Press.

Dewey, J. (1934). *Art as Experience.* Reprinted 1980. New York: Perigee Books.

Dillenbourg, P. (Ed.) (1999). *Collaborative learning: Cognitive and computational approaches*. Amsterdam et al.: Elsevier Science.

DiSessa, A. (1997) Open toolsets: new ends and new means in learning mathematics and science with computers, Proceedings of the 21st Psychology of Mathematics Education Conference, Finland, Lahti, Pekhonenen (Ed).

DiSessa, A. (2000). Changing minds, computers, learning and literacy. Cambridge, MA: MIT Press.

Grossman P., Wineburg, S. and Woolworth, S. (2000) In Pursuit of Teacher Community, paper presented at the Annual Meeting of the American Educational Research Association, New Orleans.

Hoppe, H. U., Gaßner, K., Mühlenbrock, M. & Tewissen, F. (2000). Distributed visual language environments for co-operation and learning: Applications and intelligent support. In *Group Decision and Negotiation, 9(3),* 205-220.

Hoyles, C. (1992). Illuminations and reflections – teachers, methodologies and mathematics, *Proceedings of the 16th Conference for the International Group for the Psychology of Mathematics Education, New Hampshire,* 3, 263-283.

Hoyles, C. (1993). Microworlds/Schoolworlds: The Transformation of an Innovation. In C. Keitel & K Ruthven (eds) Learning From Computers: Mathematics Education and Technology, 1-17. Berlin/Heidelberg: Springer-Verlag, pp. 1-17.

Hoyles, C., Newman, K. and Noss, R. (1997) Report on the FLYVER microworld and on components for education generally inspired by the FLYVER microworld.

Kafai, Y., Resnick, M., Eds. (1996) Constructionism in practice. Designing, thinking and learning in a digital world, Lawrence Earlbaum Associates, New Jersey.

Kaput, J., Noss, R. and Hoyles, C. (in press) Developing New Notations for a Learnable Mathematics in the Computational Era

Kontogiannopoulou - Polidorides, G. (1996) Educational paradigms and models of computer use: does technology change educational practice?, In Cross National Policies and Practices on

Computers in Education, Plomp T., Anderson, R., E. and Kontogiannopoulou – Polidorises G. (Eds). Kluwer Academic Press, Dordrecht, 49-84.

Krämer, S. (1998). Das Medium als Spur und Apparat (The medium as trace and apparatus). In Krämer, S. (Ed.), *Medien - Computer - Realität* (Media - Computers - Reality). Frankfurt/Main (Germany): Suhrkamp.

Kynigos C. (in press) Generating cultures for mathematical microworld development in a multi-organisational context, Journal of Educational Computing Research

Luhman, N. & Schorr, K. E. (19829: Das Technologiedefizit der Erziehung und die Pädagogik (Pedagogics and the technology deficit of education). In Luhman, N. & Schorr, K. E. (eds*.), Zwischen Technologie und Selbstreferenz* (Between Technology and Self-reference) (pp. 11-40). Frankfurt/Main (Germany): Suhrkamp.

McLuhan, M. (1964). *Understanding Media - The Extensions of Man*. Reprinted 1994. Cambridge (USA): MIT Press.

Noss, R. (1995) Computers as Commodities, in *Computers and Exploratory Learning*, A. diSessa, C. Hoyles and R. Noss (eds.), Springer Verlag NATO ASI Series, pp.363-381.

Papert, S. (1993) The Children's Machine, Rethinking School in the Age of the Computer, New York: Basic Books.

Pinkwart, N., Hoppe, H.U., Bollen, L. & Fuhlrott, E. (2002). Group-oriented modeling tools with heterogeneous semantics. To appear in *Proceedings of ITS 2002* (Biarritz, France, June 2002). Berlin: Springer.

Prawat R.S. (1996) Learning community, commitment and school reform, *Jnl. of Curriculum Studies*, vol. 28, No. 1, pp. 91-110.

Schwartz, D. (1999). The productive agency that drives collaborative learning. In Dillenbourg, P. (Ed.) (1999), *Collaborative learning: Cognitive and computational approaches* (pp. 197-218). Amsterdam et al.: Elsevier Science.

Tenorth, H.-E. (1994). *"Alle alles zu lehren" - Möglichkeiten und Perspektiven allgemeiner Bildung* ("To Teach Everybody Everything" - Possibilities and Perspectives of General Education). Darmstadt (Germany): Wissenschaftliche Buchgesellschaft (WBG).

Vogel, M. (2001*). Medien der Vernunft - Eine Theorie des Geistes und der Rationalität auf der Grundlage einer Theorie der Medien*. (Media of Reason - A Theory of Mind and Rationality based on a Theory of Media.) Frankfurt a. M. (Germany): Suhrkamp.

Vygotsky (1978). *Mind in Society*. Cambridge (USA): Harvard University Press.